

Chapter 13

Solutions

I) Introduction

Homogeneous mixture on a molecular level

- prop. same throughout
- separable by physical means
- variable composition

Has at least 2 components:

Solvent: component present in greatest amt.

- same phase as soln.

Solute: other component(s)

II) Types of Solutions

A) Gaseous Soln.

Miscible Fluid: fluids that mix w. or dissolve in each other in **ALL** proportions

Ex: Air (solvent is N_2)

B) Liquid Soln.

Solvent: liquid

Solute: gas, liquid, solid

Most common solvent: H_2O
Aqueous soln.

C) Solid Soln.

Most common solvent: metal

Alloys

A nickel (5¢) : 25% Ni & 75% Cu

III) Expressing Concentration

A) Qualitatively

Dilute : relatively **small amt.**
of **solute** in **soln.**

Concentrated : **large amt.** of **solute**

B) Quantitatively

1) Percent Conc.

$$\frac{\text{parts of solute}}{100 \text{ parts of soln.}} \times 100\%$$

parts per **hundred**

a) Mass % (wt./wt. %)

$$\text{mass \% of solute} = \frac{m \text{ of solute}}{m_T \text{ of soln.}} \times 100\%$$

or

$$\frac{w}{w} \% = \frac{\text{wt. of solute}}{\text{wt.}_T \text{ of soln.}} \times 100\%$$

1) Ex 1: What is the w/w% of 6.4g NaCl in 100g H₂O?

2) Ex 2: You want to make 1000g of a 2.0% soln. of AgNO₃. What mass of H₂O is req.?

b) Weight/Volume %

$$\frac{w}{v} \% = \frac{\text{wt. solute}}{V_T \text{ soln.}} \times 100 \%$$

wt. \Rightarrow grams

v \Rightarrow mL

- **liq. soln.** when **solute is solid**

c) Vol./Vol. %

$$\frac{v}{v} \% = \frac{v \text{ solute}}{V_T \text{ soln.}} \times 100 \%$$

Both volumes **must** have **same** units, generally mL

2) Parts per Million

$$\text{ppm} = \frac{\text{wt. or vol. solute}}{\text{wt. or vol. of soln.}} \times 10^6$$

$$1 \text{ ppm} = \frac{1 \text{ g solute}}{10^6 \text{ g soln}} = \frac{1 \text{ mg solute}}{\text{kg soln.}}$$

For dilute aqueous solns,

$$\text{Density} \approx \frac{1 \text{ g soln.}}{\text{ml soln}} = \frac{1 \text{ kg soln}}{\text{L soln}}$$

$$\therefore 1 \text{ ppm} \approx \frac{1 \text{ mg}}{\text{L}}$$

3) Parts per Billion

$$1 \text{ ppb} = \frac{1 \text{ g solute}}{10^9 \text{ g soln.}}$$

4) Molarity (M)

$$M = \frac{\text{moles solute}}{L \text{ soln.}}$$

5) Molality (m)

$$m = \frac{\text{moles solute}}{\text{kg solvent}}$$

For dilute aqueous solns,

$$D \approx 1 \text{ g/mL} = 1 \text{ kg/L}$$

i.e. 1 kg solvent \approx 1 L soln.

$$\therefore m \approx M$$

a) Ex : What is the molality of I_2 in a soln. of 5.00g I_2 in 30.0g of CH_2Cl_2 ?

6) Mole Fraction (χ_A)

$$\chi_A = \frac{\text{moles substance } A}{\text{Total moles soln.}}$$

$$\text{Mole \%} = \chi_A \times 100 \%$$

$$\sum_i \chi_i = 1$$

a) Ex: What are the mole fractions of I_2 & CH_2Cl_2 in the previous ex.?

7) Converting Conc. Units

Need definitions, MW, density

a) Ex 1: Determine molarity of
5.06 m $C_2H_4(OH)_2$ (ethylene glycol).

$$D = 1.045 \text{ g/mL} \quad MW = 62.08 \text{ g/mol}$$

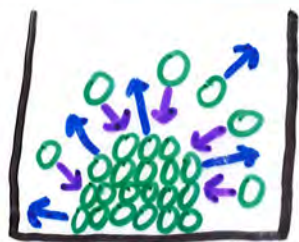
b) Ex 2: An aqueous soln. of ethanol (C_2H_5OH) is $14.1\text{ M } C_2H_5OH$. The density of the soln. is 0.853 g/cm^3 . What is the molality of ethanol in the soln.?

c) Ex 3: Antifreeze soln. is 23.9% (wt%) ethylene glycol ($C_2H_4(OH)_2$) in H_2O . The density of the soln. is 1.045 g/mL

- What are the mole fractions of the components?
- What is the molarity of soln.?

IV) Solubility

50 g NaCl in 100 g H₂O



14 g solid remain



A soln. in equilibrium w.

undissolved solute is

Saturated

Solubility

conc. (amt.) of solute in a saturated soln.

g solute / 100 g solvent

Solubility of NaCl at 20°C,

$$\frac{36.0\text{g NaCl}}{100\text{g H}_2\text{O}} \approx \frac{36.0\text{g NaCl}}{100\text{ mL H}_2\text{O}}$$

What if have 30g NaCl in 100g H₂O?

ALL solute dissolves & soln.
contains less than equil. amt.

Un saturated

Super saturated soln.

Contains more solute than
a saturated soln.

V) The Solution Process

Solute dissolves in solvent
& is surrounded by solvent
particles

Solvation

Due to **IAF** between
solute & solvent

When

Solute \Rightarrow Ions

Solvent \Rightarrow H_2O

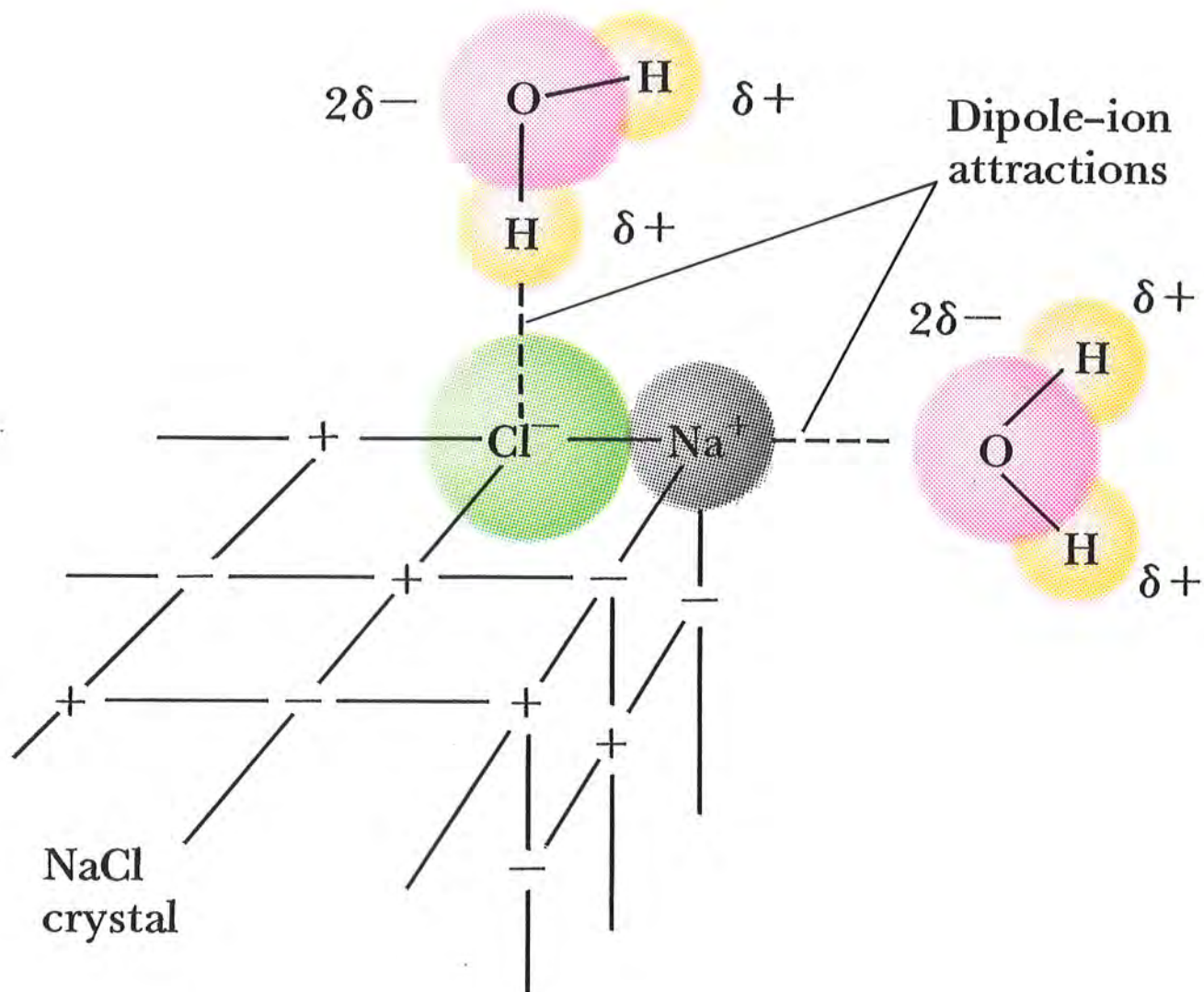
IAF \Rightarrow Ion-Dipole Forces

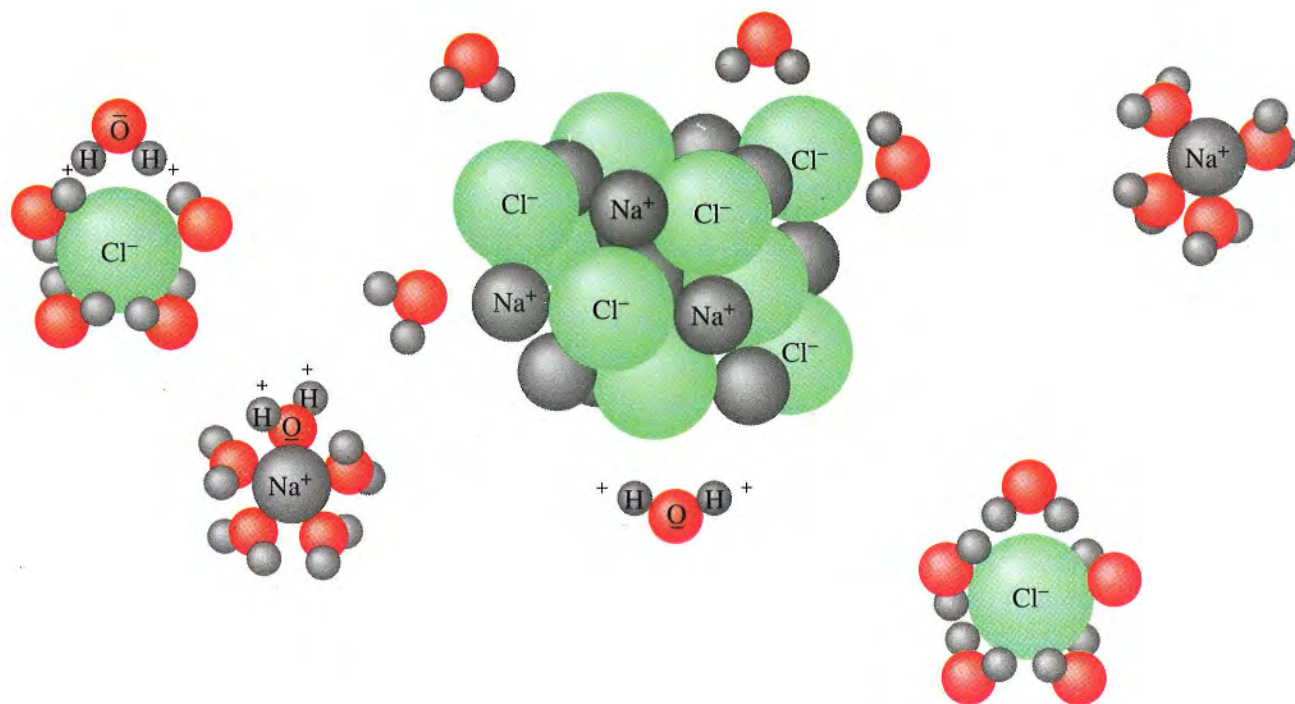
Attraction of Ions for H_2O :

Hydration

Transparency 92

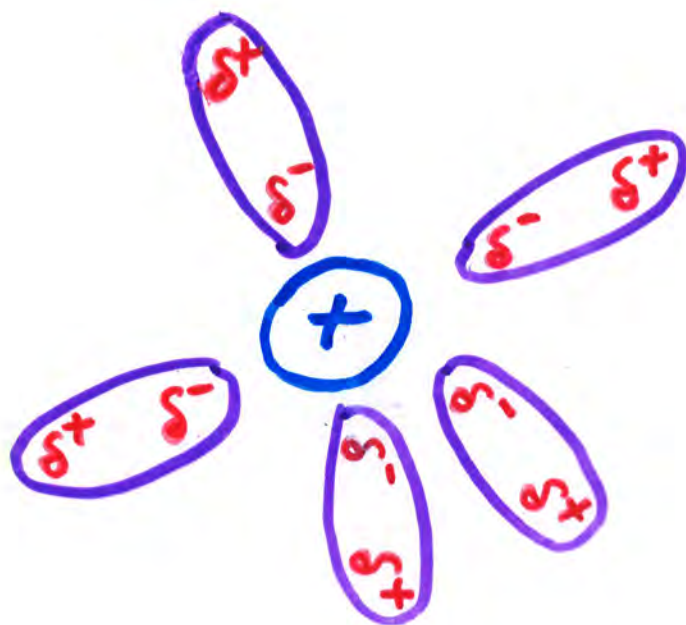
Figure 13.1 Interaction between H₂O molecules and the ions of NaCl crystal





Ion-Dipole Forces

Ions & Polar molecules



Magnitude of interaction:

$$E \propto \frac{Q\mu}{d^2}$$

$Q \equiv$ charge on ion

$\mu \equiv$ dipole moment of dipole

$d \equiv$ distance from center of ion to midpoint of dipole

A) Energy Considerations

1) Solute - Solute Interactions

separate solute particles

- break IAF between like particles



Endothermic, $\Delta H_1 > 0$

2) Solvent - Solvent Interactions

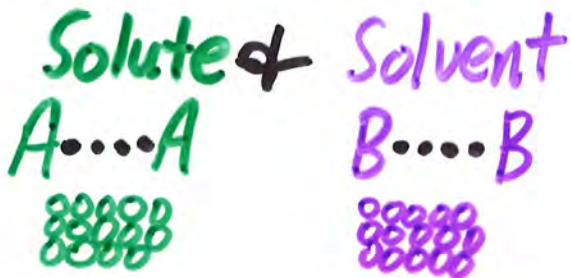
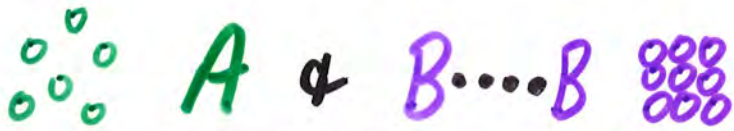
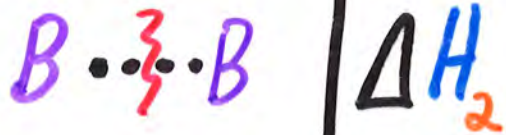


3) Solute - Solvent Interactions

Form IAF between solute & solvent particles



Exothermic, $\Delta H_3 < 0$



4) Enthalpy of Solution

$$\Delta H_{\text{soln}} = \Delta H_1 + \Delta H_2 + \Delta H_3$$

$$\Delta H_1 = \Delta H_{\text{separate solute}}$$

$$\Delta H_2 = \Delta H_{\text{separate solvent}}$$

$$\Delta H_3 = \Delta H_{\text{solvation}}$$

a) Ideal Soln.

$$\Delta H_{\text{soln}} = 0$$

similar IAF between all particles

Ex: SiCl_4 in CCl_4

b) Endothermic Case

$$\Delta H_{\text{soln}} > 0 \text{ heat absorbed}$$

solute-solvent **IAF**

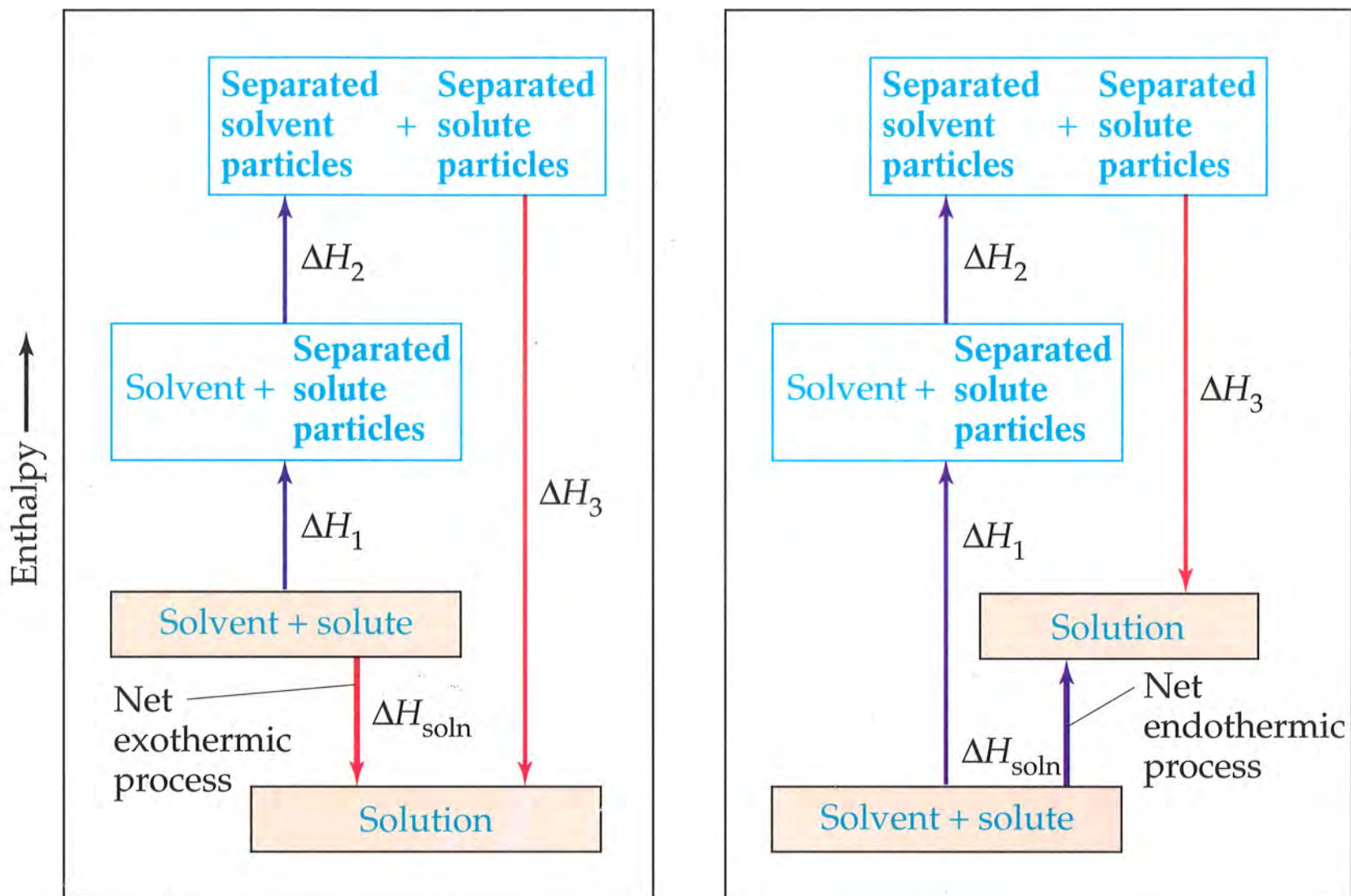
weaker than solute-solute
& solvent-solvent **A.F.**

unlike forces < like forces

$$|\Delta H_{\text{solvation}}| < \Delta H_{\text{sep. solute}} + \Delta H_{\text{sep. solvent}}$$

Ex: most salts in H_2O

Fig. 13.3 Analysis of Enthalpic Changes



1) salts in H₂O

$$\Delta H_{\text{sep. ions}} = LE$$

$$\Delta H_{\text{solvation}} = \Delta H_{\text{hydration}}$$

$$\Delta H_{\text{sep. H}_2\text{O}} \approx 0$$

$$\Delta H_{\text{soln}} = L.E. + \Delta H_{\text{hyd}}$$

$\Delta H_{\text{soln}} > 0$ for most salts

Note: As charge density inc.
solubility dec.

$$|L.E.| \gg \Delta H_{\text{hyd}}$$

2) Ex: The heat of soln. for a particular substance is 65.0 kJ/mol . The lattice energy is 575.0 kJ/mol . What is the hydration energy?

c) Exothermic Case

$\Delta H_{\text{soln}} < 0$ heat evolved

solute-solvent IAF

stronger than solute-solute
& solvent-solvent A.F.

unlike forces > like forces

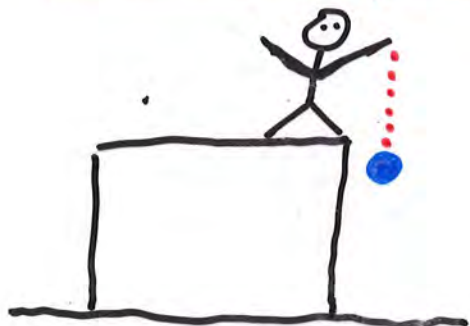
1) Ex: H_2SO_4 in H_2O



2) Ex: most gases in H_2O

B) Soln. Formation, Entropy, Spontaneity

1) Enthalpy Change, ΔH_{soln}



potential energy
dec.

- loses energy
- spontaneous

$$\Delta H < 0$$

- results in a lower enthalpy state for system

Processes in which energy content of system dec. tend to occur spontaneously

2) Entropy Change, ΔS_{soln}

measure of **disorder**
(**randomness**) in a system.

Process tends to occur **spont.**
if change results in **inc.** in **disorder**

$$\Delta S > 0$$

Generally, true for **soln.** formation

3) Free Energy, ΔG

measure of **chem. potential**

$$\Delta G = \Delta H - T\Delta S$$

$$\Delta G < 0, \text{ spont.}$$

$$\Delta G > 0, \text{ nonspont.}$$